

THE ELECTROENCEPHALOGRAM OF THE
FRONTAL LOBES AND ABSTRACT
BEHAVIOR IN OLD AGE

By
WILL ALAN JUSTISS

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Chapter I

INTRODUCTION AND STATEMENT OF PROBLEM

A. Purpose

It was the purpose of this study to test the hypothesis that: The degree of impairment of abstract behavior in old age is related to the kind and amount of electrical activity of the frontal lobes of the brain.

B. Abstract Behavior

According to King (1) the idea that impairment of abstract behavior is related to damage of the frontal lobes of the brain goes back to the work of Gelb and Goldstein which was done during and after World War I on brain damaged patients.

By means of highly specialized tests they were able to differentiate between normals and brain injured. They found the normal subjects were capable of two modes of approach in solving the problems presented by the tests. The first was a concrete approach and the second was an abstract approach to the problems. The normals could assume either approach whereas the brain damaged could assume only the concrete.

Goldstein and Scheerer (2) list as the basis for the abstract attitude the ability: (1) to shift reflectively from one aspect of a situation to another, (2) to

hold in mind simultaneously various aspects of a situation, (3) to grasp the essentials of a given whole; to break up a given whole into parts, to isolate and synthesize them, (4) to abstract common properties reflectively, (5) to form heirarchic concepts and, (6) to plan ahead ideationally, to assume an attitude toward the "mere possible" and to think or perform symbolically.

Concrete behavior as described by them does not imply conscious activity in a sense of reasoning, awareness or self account of one's doings. They state that:

"We surrender to experience of an unreflective nature; we are confined to the immediate apprehension of a given "thing" or situation in its particular uniqueness. (. . .) In a sense the subject or individual is stimulus bound, that is, he can only respond to the "thing" properties of the stimulus rather than to the general nature, class, or category of a thing."

Halstead (3) in an investigation of intelligence and brain damage isolated four factors one of which he calls a factor of abstraction. He states that:

"(. . .) this factor concerns a basic capacity to group to criterion, as in the elaboration of categories, and involves the comprehension of essential similarities and differences."

Halstead's investigation involved three groups of subjects, (1) control group of young normals, (2) a brain damaged group and (3) a frontal lobectomy group. He

found that the frontal lobectomy patients' performance on the tests of abstract behavior was the poorest of the three groups' and that the brain damaged groups performance was poorer than the control subjects. The differences in performance between the controls and the frontal lobectomy patients were significant at better than the .01 level of confidence. These results led Halstead to state that:

"(. . .) while the ability for abstract behavior is represented throughout the cerebral cortex its representation is not equal throughout. It is distributed in a gradient with its maximal representation occurring in the cortex of the frontal lobes."

C. Electroencephalographic (EEG) Studies

Obrist (4) in an EEG study found that the EEG's of persons over age 65 exhibit a greater incidence of delta activity in the frontal regions of people over 80 years of age, a marked decrease in the rate of (occipital) alpha rhythm, a slight trend toward less (occipital) alpha rhythm and a tendency toward paroxysmal fast activity.

Obrist (4) using Gibbs' and Gibbs' (5) method of classifying EEG's found significant relationships between performance on the Wechsler-Bellevue Intelligence Test and EEG Classifications.

Silverman et al (6) and Silverman et al (7) have noted relationships between the EEG and senile deterioration

which strongly suggest that mental deterioration is related to specific EEG patterns.

In an investigation of aging and abstract concrete-behavior Thaler (8) found only a chance relationship between an individual's performance on the Weigel test and his EEG classification. In her study the method of Gibbs and Gibbs (5) was used to classify EEG's the classifications being: normal, focal, mixed and diffuse.

It may be noted at this point that these categories are ratings of the EEG as a whole and do not necessarily include the information that the EEG may exhibit sections that are normal and sections that are abnormal.

In general, previous studies of the relationship between intelligence and the EEG have used the method of Gibbs and Gibbs (5) of classifying EEG's and relating the categories to performance on standardized intelligence tests. In contrast to the above method this investigation attempts to relate performance on tests of abstract behavior to per cent time activity of certain EEG frequencies occurring in a specific anatomical area of the brain.

CHAPTER II

Apparatus and Procedure

A. Apparatus

Electroencephalograms.

1. Electroencephalograms.-- An eight channel Grass EEG, Model III D, was used to record brain waves. Silver disc electrodes, 8 mm in diameter, were attached to the scalp of the subject by means of Bentonite paste. Mono-polar and bipolar recordings were taken in the following sequence: (1) 1, 2, 3, 4, 5, 6, 7, 8 to 9 + 10 NG, (2) 1, 2, 3, 4, 5, 6, 7, 8, 9 to NG, (3) 1-11, 11-3, 2-12, 12-4, 11, 12, 7, 8 to NG, (4) 1-3, 3-5, 2-4, 4-6, 7-3, 3-4, 4-8, 8-7 to NG, (5) 1-7, 7-5, 5-6, 6-8, 8-2, 2-1, 8-7, 9-10 to NG.

At least 200 seconds of record was obtained in each of the above sequences.

2. Electrode placement.-- All electrode placements were standard with respect to the mid-line of the head. Location of the electrodes was as follows; (1) frontal electrodes were placed 3.5 cm to the right and left of the mid-line. They were placed one half the distance between the vertex and the glabella; (2) parietal electrodes were placed 3.5 cm to the right and left of the mid-line and were approximately 3 cm posterior to the vertex;

(3) occipital electrodes were anterior to the occipital protuberance and 3.5 cm to the right and left of the mid-line; (4) mid-temporal electrodes were placed on a line from the vertex to the tragus and mid-way between the tragus and the sagittal plane; (5) anterior temporal electrodes were placed on Frankfurter's plane about 3 cm posterior to the outer canthus of the eye; (6) reference electrodes were placed on the lobes of the ears. (Fig. 1).

3. Calibration.-- Square wave calibration was taken at the beginning and end of each record, with muscle filters both on and off. All channels were calibrated with 50 microvolts being equal to 7 mm deflection.

All EEG's were recorded in the Moosehaven Research Laboratory, Orange Park, Florida. This section of the Laboratory was especially designed for EEG work and is shielded against outside electrical interference. Extraneous noise was kept to a minimum and a comfortable temperature was maintained by air conditioning.

Tests of abstract behavior.

1. The Grassi Block Substitution Test for Measuring Organic Brain Pathology (9).-- This test

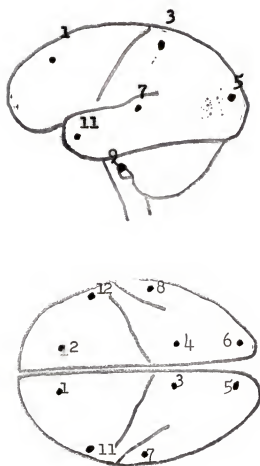


Fig. 1. Schematic representation of brain. Dots show areas over which scalp electrodes were placed.

was validated on known cases of intra-cranial pathology and normal controls. The reliability was satisfactorily established by the test, re-test method. The total accuracy score possible is twenty points with a possible ten additional points that may be earned through time credits.

2. The Porteus Maze Test (10).-- The results obtained on the test in the Columbia Greystone Project (1) led Porteus (10) to state that the results:

" (. . .) prove clearly that surgical interference with the functions of the frontal lobes either by lobotomy or topectomy is reflected in strongly impaired Maze performance (. . .)."

Included in the notion that the test measures foresight, planning and prudent initiative are the concepts of abstract and concrete thinking. The test was therefore included in the test battery as it met the two criteria of empirical validation of the test against known intracranial pathology and that high scores on the test would be evidence of abstract thinking.

3. Halstead Performance Test (Speed) (3).-- Three timed trials are given; the first with the dominant hand only, the second with the other hand and the third with both hands. The score is the average of the three tests.

4. Halstead Performance Test (Recall) (3).-- Following the three timed without vision the subject is

asked to draw an outline of the board as he imagines it to be, including the shapes of the various blocks and their location on the board. The number of shapes out of ten accurately recalled constitutes the score on this test.

5. Halstead Performance Test (Localization) (3).--

The score on this test is the number of shapes out of ten accurately localized.

Halstead found that these tests involve the factor of abstraction and that they discriminate between normal controls and frontal lobectomy patients at better than the .01 level of significance.

B. Procedure

Subjects.-- The subjects were thirty male residents of Moosehaven, Orange Park, Florida. The median age of the group was 76 years. The youngest of the group was age 66 while the oldest was age 92. All volunteered to take the battery of tests and no remuneration was paid for their participation. All were interested in the research and seemed to put out their best efforts.

The subjects selected were free from gross physical handicaps that could have interfered with

their performance on the test. Vision and hearing were in all cases adequate to the tasks.

In accordance with the hypothesis of the study a wide range of performance was needed; therefore, some subjects were selected who were bright, alert and holding down high level jobs at Moosehaven, such as Secretary of the Lodge, and others were selected who were not able to work on a simple job like setting the table in the dining room. The basis of selection was not whether the subject was or was not on the work program but on his general level of functioning. It may be noted in the results that a wide range of performance on the tests was obtained.

Analysis of EEG's.-- The EEG's were analyzed in terms of the per cent of the time that the following rhythms were present in the frontal lobes during the recording on sequence number four: delta (2-5.9 cps); theta (6-6.9 cps); alpha (7-12.9); and beta (above 13 cps).

The per cent of the time that each of the above frequency categories was present was calculated by selecting a 20 second sample of each record that appeared to be representative of a waking, relaxed

state. Delta rhythms were then underlined in green, theta rhythms underlined in black, alpha rhythms underlined in red and finally beta rhythms were underlined in blue.

The length of the green lines was then measured in millimeters, summated and multiplied by the reciprocal of 600 to yield the per cent of the time that delta rhythms were present. (The reciprocal of 600 is used because 20 seconds of recording at a paper speed of 3 cm second yields 600 linear mm of recording).

The above procedure was repeated for delta, theta, alpha and beta rhythms to obtain the per cent of the time that they were present.

Each EEG record, therefore, yielded four values that could be statistically related to the scores on the tests of abstract behavior.

Analysis of abstract behavior tests.-- The analysis of the tests of abstract behavior yielded the following scores that were statistically related to the EEG's. (1) Grassl Block Substitution Test total score, (2) Grassl Block Substitution Test complex total, (3) The Porteus Maze Test, (4) Halstead Performance Test (Speed)

score, (5) Halstead Performance Test (Recall) score, (6) Halstead Performance Test (Localization) score.

Statistical Comparisons.-- Pearson product-moment correlations were calculated between (1) per cent time frontal alpha and per cent time frontal beta, (2) per cent time frontal alpha and the Grassi Test total score, the Porteus Maze test age and the Halstead Test (Recall) score and (3) the per cent time frontal alpha with the mean occipital alpha frequency.

Multiple coefficients of correlation (11) were calculated between the per cent time frontal alpha with the Grassi total and Porteus test age combined, and the per cent time frontal alpha with the Grassi complex total and Porteus test age combined.

Median tests (12) were calculated between age and (1) per cent time frontal alpha, (2) Grassi total score and (3) Porteus test age.

Controls.-- Wechsler-Bellevue Intelligence Scale (13) I.Q.'s were obtained on all subjects. Twenty-one of the subjects had taken the test within about one year previous to the study and the writer administered the test to the remaining nine. The purpose of this test was to insure obtaining subjects whose I.Q.'s were, or had

been, above ninety I.Q. points. This precaution was taken in order to eliminate subjects of below normal intelligence. The mean I.Q. for the group was 105.4 and the range of scores was from 91 to 131.

In order to obtain EEG records that were free from muscle tension artifacts all recordings were taken with the muscle filters on. This precaution eliminated the ambiguity inherent in "reading out" muscle artifacts.

In all cases a sample of the EEG record was analyzed that showed some occipital alpha rhythm while the subjects' eyes were closed. The samples were taken as soon after the eyes were closed as possible in order to lend comparability to the cerebral states of the subjects.

Coefficients of correlations were computed between the scores on the various tests and millimeters of activity present for the various rhythms. This procedure was followed to minimize the effect of rounding numbers when converting the raw scores to percentages. The term per cent time present was used as it was felt to be a more meaningful term than the term millimeters of activity.

An additional control was the selection of subjects whose language was no barrier to the comprehension of instructions on the various tests. This precaution was necessary as there are numerous residents of Moosehaven of European birth.

Chapter III

RESULTS

Delta and theta rhythms.-- Table 1 illustrates the amount of delta and theta activity of the frontal lobes of 30 subjects. It may be noted that only one subject exhibited delta activity and one subject theta. To gain an idea of the minimal amount of these rhythms we may observe that 18,000 mm of record were measured and out of this amount, delta and theta rhythms were present for only 390 mm.

Alpha and Beta rhythms.-- A wide range of variability for both alpha and beta frontal rhythms may be observed in Table 2. Only two subjects out of 30 exhibited no alpha activity and only one subject exhibited no beta activity. A Pearson product-moment correlation between the distributions of scores in Table 2 yielded a coefficient of correlation of $-.504$. With 28 degrees of freedom this value is significant at better than the .01 level of confidence. This inverse relationship indicates that small amounts of beta activity are related to large amounts of alpha activity and large amounts of beta activity are related to small amounts of alpha activity.

It should be mentioned at this point that the per cent of the time that various rhythms are present

TABLE 1

PER CENT TIME FRONTAL LOBE ACTIVITY OF DELTA AND THETA RHYTHMS

Subject Number	Delta	Theta	Subject Number	Delta	Theta
1	0	0	16	0	0
2	44.8	0	17	0	0
3	0	0	18	0	0
4	0	0	19	0	0
5	0	0	20	0	0
6	0	0	21	0	0
7	0	19.7	22	0	0
8	0	0	23	0	0
9	0	0	24	0	0
10	0	0	25	0	0
11	0	0	26	0	0
12	0	0	27	0	0
13	0	0	28	0	0
14	0	0	29	0	0
15	0	0	30	0	0

TABLE 2

PER CENT TIME FRONTAL LOBE ACTIVITY OF ALPHA AND BETA RHYTHMS

Subject Number	Alpha	Beta	Subject Number	Alpha	Beta
1	30.7	98.8	16	82.0	39.5
2	0	100.0	17	94.0	91.0
3	91.7	26.5	18	100.0	0.0
4	13.8	95.3	19	87.2	100.0
5	92.8	29.2	20	29.7	100.0
6	85.8	100.0	21	84.7	68.3
7	80.0	13.8	22	48.5	92.2
8	15.8	95.8	23	99.2	0.0
9	88.8	15.7	24	79.3	71.3
10	86.5	13.5	25	95.8	11.0
11	57.0	89.5	26	60.3	100.0
12	0	100.0	27	80.5	69.0
13	36.7	96.0	28	44.2	100.0
14	12.7	100.0	29	86.9	37.1
15	36.2	79.8	30	62.8	46.1

in the frontal lobes may exceed 100 per cent. The explanation for this lies in the fact that fast rhythms may be "riding" on top of slower rhythms.

Per cent time frontal alpha and Grassi total.--

The range of per cent time frontal alpha varied from 0.0 to 100.0 and the range of scores on the Grassi test varied from 1.0 to 20.5. In an effort to determine whether performance on the Grassi test was related to frontal alpha activity, a Pearson coefficient of correlation was calculated. The distributions are entered in Table 3 and the coefficient of correlation of $-.208$ is entered in Table 4. This low negative non-significant correlation indicates that little relationship exists between per cent time frontal alpha activity and total scores on the Grassi test.

Per cent time frontal alpha and Porteus test age.--

The distributions of per cent time frontal alpha and Porteus test age are entered in Table 5. Porteus test age scores vary from five years to 17 years and alpha activity varies from being present none of the time to being present all of the time. A comparison of these distributions yielded a negative correlation of $-.424$ which is entered in Table 4. At 27 degrees of freedom this value is significant at better than the .05 level of significance.

TABLE 3

PER CENT TIME FRONTAL ALPHA ACTIVITY AND GRASSI TOTAL SCORE

Subject Number	Per cent Time Frontal Alpha	Grassi Total Score	Subject Number	Per cent Time Frontal Alpha	Grassi Total Score
1	30.7	20.5	16	82.0	17.5
2	0.0	17.0	17	94.0	3.0
3	91.7	10.0	18	100.0	7.0
4	13.8	6.5	19	87.2	9.5
5	92.8	2.0	20	29.7	12.5
6	85.8	17.5	21	84.7	12.0
7	80.0	8.5	22	48.5	1.0
8	15.8	12.5	23	99.2	7.5
9	88.8	7.5	24	79.3	13.5
10	86.5	9.5	25	95.8	14.0
11	57.0	17.5	26	60.3	5.0
12	0.0	5.0	27	80.5	5.0
13	36.7	17.0	28	44.2	14.0
14	12.7	11.0	29	86.9	11.0
15	36.2	10.5	30	62.8	12.0

TABLE 4

CORRELATIONS OF PER CENT TIME FRONTAL ALPHA
AND TESTS OF ABSTRACT BEHAVIOR

	Grass1 Total Score	Porteus Maze Test Age	Halstead Recall Test
Percent Time Frontal Alpha	-.208	-.424*	-.047

N = 30

N = 29

N = 29

*Significant at better than the 5%
Level of Confidence.

The other r's in this table are
not significant.

TABLE 5

PER CENT TIME FRONTAL ALPHA ACTIVITY AND PORTEUS TEST AGE

Subject Number	Per cent Time Frontal Alpha	Porteus Test Age	Subject Number	Per cent Time Frontal Alpha	Porteus Test Age
1	30.7	13.5	16	82.0	8.0
2	0.0	16.5	17	94.0	7.0
3	91.7	12.0	18	100.0	7.0
4	13.8	13.5	19	87.2	12.0
5	92.8	5.0	20	29.7	8.0
6	85.8	11.5	21	84.7	6.0
7	80.0	-	22	48.5	5.5
8	15.8	8.0	23	99.2	11.0
9	88.8	8.5	24	79.3	13.5
10	86.5	7.0	25	95.8	7.5
11	57.0	12.0	26	60.3	7.5
12	0.0	14.0	27	80.5	5.5
13	36.7	8.0	28	44.2	17.0
14	12.7	8.5	29	86.9	9.0
15	36.2	12.5	30	62.8	13.5

This indicates that low scores on the Porteus Maze Test are associated with large amounts of frontal alpha activity and that high scores are associated with small amounts of alpha activity.

Subject number seven in Table 5 did not take the test due to illness.

Per cent time frontal alpha and Halstead Tests.--
The performance score of all subjects on the Halstead tests are tabulated in Table 6. Per cent time frontal alpha values are entered in Table 5. It may be noted in Table 6 that only 14 subjects had speed test scores. Of the 16 subjects who have no scores, 15 could not complete the test and one was able to see the blocks and therefore invalidated the results.

A coefficient of correlation was calculated between the distribution of per cent time alpha scores and the Halstead Recall Test. This procedure yielded the low negative correlation of $-.047$ which is entered in Table 4. This value indicates that performance on the Halstead Recall Test and per cent time frontal alpha are statistically not significantly related.

Due to the restricted range of the Localization Test and the incomplete data of the Speed Test in Table 6

TABLE 6

HALSTEAD SPEED RECALL AND LOCALIZATION TESTS

Subject Number	Speed	Recall	Local- ization	Subject Number	Speed	Recall	Local- ization
1	4.3	4	1	16	-	0	0
2	4.8	3	0	17	9.3	3	2
3	-	-	-	18	-	0	0
4	17.9	4	0	19	-	0	0
5	-	0	0	20	5.9	3	0
6	14.8	6	1	21	19.4	0	0
7	-	3	0	22	-	0	0
8	-	0	0	23	-	0	0
9	13.4	6	1	24	7.3	5	0
10	-	1	0	25	-	7	3
11	-	4	2	26	-	2	0
12	-	0	0	27	10.7	0	0
13	10.9	6	2	28	7.8	7	0
14	-	1	0	29	-	2	0
15	15.8	3	0	30	9.3	6	0

further statistical comparisons of the Halstead Tests and the EEG were not attempted.

Frontal alpha related to Porteus Test age and Grassi Total combined.-- A multiple coefficient of correlation was calculated between per cent time frontal alpha with Porteus Test Age score and Grassi total score combined. From Table 7 it may be seen that the multiple correlation coefficient between the above variables resulted in a value of $-.424$ that is significant at better than the .05 level of significance. The confidence limits for r in terms of a T criterion of 2.0 are equal to correlation coefficients of $-.464$ and $-.384$. We can therefore assume that the sample result of $-.424$ was derived from a universe whose product-moment correlation coefficient was at least $-.384$ but not greater than $-.464$. These values are the limits of reliability of the sample r .

Designs completed on Grassi Test.-- Levels of difficulty with number of designs completed by the group at each level are illustrated in Table 8. As there are five steps at each level of difficulty the maximum mean possible at each level is five. It may be seen that as the complexity of the task increases the average number completed at each level decreases. It may also be noted

TABLE 7

MULTIPLE COEFFICIENT OF CORRELATION
BETWEEN FRONTAL ALPHA WITH PORTEUS TEST AGE AND
GRASSI TOTAL COMBINED

TESTS		
1	2	3
	Porteus Test Age	Grassi Total
Per cent Time Frontal Alpha	$\bar{r}_{1.23} = -.424^*$	

* $\bar{F} = 5.93$. $\bar{r}_{1.23}$ is significant at better than the 5% level of confidence.

*Confidence (or Fiducial) limits of $\bar{r}_{1.23} = -.424 \pm .04$.

* TABLE 8

TOTAL DESIGNS COMPLETED BY SUBJECTS AT EACH
LEVEL OF DIFFICULTY OF THE GRASSI BLOCK
SUBSTITUTION TEST

Level	Total Correct for Group	Mean
Simple Concrete	132*	4.4**
Simple Abstract	81	2.7
Complex Concrete	65	2.2
Complex Abstract	25	.9

*Note: The maximum Total for each Level = 150

**Maximum Mean at each Level = 5

N = 30

that the total number of designs completed at the complex levels total only 90, whereas the total completed at the simplex levels total 213. Analysis of total points earned by each subject for the complex concrete and the complex abstract levels are entered in Table 9 with per cent time frontal alpha. The break-down of points earned on the Grassi Test by levels was undertaken as it was noted that a subject's total score could be earned in a variety of ways at the lower levels, but that the complex levels more adequately discriminated between subjects. Table 10 illustrates the tasks involved at various levels of the test.

Frontal alpha related to Porteus Test Age and Grassi complex total combined.-- A multiple coefficient of correlation was calculated between per cent time frontal alpha with Porteus test age and Grassi complex total, scores combined. From Table 11 it may be seen that the multiple correlation coefficient between the above variables resulted in a value of $-.488$ that is significant at better than the $.01$ level of confidence. The confidence limits for this correlation in terms of a T criterion of 2.0 are equal to correlations of $-.528$ and $-.448$. We can therefore be confident that the sample result of $-.488$ was derived from a universe

TABLE 9

PER CENT TIME FRONTAL ALPHA ACTIVITY AND GRASSI COMPLEX TOTAL

Subject Number	Per cent Time Frontal Alpha	Grassi Complex Total	Subject Number	Per cent Time Frontal Alpha	Grassi Complex Total
1	30.7	9	16	82.0	6
2	0.0	9	17	94.0	0
3	91.7	5	18	100.0	0
4	13.8	3	19	87.2	1
5	92.8	0	20	29.7	4
6	85.8	5	21	84.7	0
7	80.0	1	22	48.5	0
8	15.8	4	23	99.2	1
9	88.8	0	24	79.3	3
10	86.5	1	25	95.8	4
11	57.0	8	26	60.3	1
12	0.0	1	27	80.5	1
13	36.7	4	28	44.2	6
14	12.7	1	29	86.9	3
15	36.2	4	30	62.8	5

TABLE 10

LEVELS OF THE GRASSI BLOCK SUBSTITUTION TEST

Level	Task for Subject
Simple concrete	to copy the top of the four stimulus blocks using the same color and same design
Simple abstract	to copy the design on the top by using different colors
Complex concrete	to copy the top and the sides using the same colors and the same design
Complex abstract	to copy the design on the top and sides by using different colors

TABLE 11

MULTIPLE COEFFICIENT OF CORRELATION
BETWEEN FRONTAL ALPHA WITH PORTEUS TEST AGE AND
GRASSI COMPLEX TOTAL COMBINED

TESTS		
1	2	3
	Porteus Test Age	Grassi Complex Total
Per cent Time Frontal Alpha	$r_{1.23} = -.488^*$	

* $F = 8.43$. $r_{1.23}$ is significant at better than the 1% level of confidence.

*Confidence (or Fiducial) limits of $r_{1.23} = -.488 \pm .04$.

whose product-moment correlation was at least $-.448$ but not more than $-.528$. These are the limits of reliability of the sample r .

Age in relation to test performance and per cent time frontal alpha.-- Median tests as described by McNemar (12) were calculated between tests of abstract behavior, per cent time frontal alpha and age. The results are entered in Table 12. The chi-square between age and Porteus test age equals 0.1, between age and Grassi total score equals 0.0, and between age and per cent time frontal alpha equals 0.05. These values vary from $P = .80$ to $P = .99$ which indicate that a strong bias was inherent in the selection of the subjects. These results are consistent with the selection procedure as described in Chapter II.

Occipital alpha frequency and per cent time frontal alpha.-- Using the method described by Justiss (14) to calculate occipital alpha frequency a mean value, in cycles per second, was obtained for each subject. The mean occipital alpha frequency was then correlated with per cent time frontal alpha to yield a low negative non-significant correlation coefficient of $-.135$ which indicates little relationship exists between the amount of frontal alpha present and the frequency of the occipital alpha.

TABLE 12

MEDIAN TESTS OF AGE IN RELATION TO TESTS OF
ABSTRACT BEHAVIOR AND OF PER CENT TIME FRONTAL ALPHA

	Porteus Test Age	Grassi Total Score	Per cent Time Frontal Alpha
Age	$\chi^2 = 0.10^*$ N = 29	$\chi^2 = 0.00^*$ N = 30	$\chi^2 = 0.05^*$ N = 30
	$\underline{*P} = .90$	$\underline{*P} = .99$	$\underline{*P} = .80$

Chapter IV

DISCUSSION

The results of the study indicate that the amount and frequency of the electrical activity of the frontal lobes is related to the ability to engage in abstract thinking.

The results also indicate that as impairment of abstract behavior progresses fast rhythms in the beta range drop out gradually (in terms of amount present) and are replaced by slower rhythms in the alpha frequency range.

This inverse relationship between amount of fast and slow frontal rhythms is also reflected in the inverse relationship between amount of alpha activity and degree of impairment of abstract behavior. This is to say that as the amount of alpha activity increases, performance on tests of abstract behavior decreases.

It is interesting to note at this point that support for these results are present in the work and theoretical position of Heath (15). He advanced the hypothesis that:

"(. . .) functional circuits existed in the brain, one which facilitated mental activity and bodily processes and another which inhibited such activity."

He presented evidence that:

"Recordings during stimulation have indicated interconnections between the frontal cortex and septal region and between the septal region and the frontal and temporal cortex."

In view of the inverse relationships presented in this study it appears that the presence of large amounts of alpha activity in the frontal regions may be exerting an inhibiting effect on the mental processes involved in abstract behavior. The reverse of this appears to be that large amounts of frontal beta activity appear to exert a facilitative effect on mental activity.

These results can also be supported by the work of Halstead (3) in experimental anoxia and abstract behavior and of Maag (16) in his work with experimental hypoxia (anoxia) and abstract behavior. Both investigators found that as anoxia increases, impairment of abstract thinking increases.

At a cortical tissue level of interpretation these results can be explained in terms of metabolic disorders that impede the normal respiration rate of the cells. Gibbs and Gibbs (17) point out that an excess (or lack) of oxygen, CO_2 or glucose will cause an increase in the oscillation rate of the neurons.

If any of these conditions becomes profound, slowing ensues and, if not reversed, death follows.

As the direction of the change in amount of frontal activity is toward slowing with the attendant impairment of abstract behavior, it appears that the results of the study are also compatible with a metabolic disorder explanation.

The results of relating age to EEG and to tests of abstract behavior uphold the idea that chronological age per se is an impure parameter and also uphold the original criterion for the selection of subjects. We may recall that subjects were selected who exhibited various levels of deterioration and that age was not considered a pertinent parameter of the study.

Subjects were selected from an aged group in order to obtain various levels of impairment of abstract behavior. In the opinion of the writer subjects could have been selected from any group that exhibited a wide range of social inadequacy with an attendant wide range of performance on the psychological tests. This is not to say that the EEG results would be the same on a younger group but we may speculate that the EEG variations would be related to abstract behavior.

Previous work in the field of EEG and the qualitative aspects of thinking have to date been scattered. Conflicting theoretical positions of the British and American "schools" on whether brain waves are the "warp and woof" of the mind or merely the metabolic output of millions of neurons have divided investigators in investigating the "meaning" of the EEG.

This investigation was undertaken with the bias that brain waves are related to thinking and may therefore be "decoded" with the proper techniques.

In conclusion it seems appropriate to comment that automatic frequency analysis of the rhythms of the frontal lobes with appropriately sophisticated psychological tests are needed to determine the reliability and validity of the results of this study.

Chapter V

SUMMARY AND CONCLUSION

Summary.-- The problem investigated was whether performance scores on psychological tests of abstract behavior are related to the electrical activity of the frontal lobes.

Thirty aged males were given The Grassi Block Substitution Test for Measuring Organic Brain Pathology, The Porteus Maze Test, Halstead Performance Test (Speed), Halstead Performance Test (Recall) and Halstead Performance Test (Localization).

Full scale EEG's were obtained on all subjects. Analysis of EEG's yielded per cent time present values for frontal; delta, theta, alpha and beta rhythms. Further EEG analysis yielded a mean occipital alpha frequency value for each subject.

The per cent time values for delta and theta rhythms were so rare that no statistical analysis was advisable.

Per cent time frontal alpha activity and beta activity were found to be significantly negatively related.

Per cent time frontal alpha activity was found to be unrelated to Grassi Test total scores.

Per cent time frontal alpha activity was found to be significantly negatively related to Porteus Test, test age, scores.

Scores on the Halstead Tests were in general so low and so restricted in range that little statistical analysis was attempted. No significant relationships were found.

Per cent time frontal alpha activity was found to be significantly negatively related to Grassi Test total score combined with Porteus Test, test age, score.

Per cent time frontal alpha activity was found to be significantly negatively related to Grassi Test complex total score combined with Porteus Test, test age, scores.

Per cent time frontal alpha activity was found to be unrelated to mean occipital alpha frequency.

Conclusion.-- The original hypothesis, that the degree of impairment of abstract behavior in old age is related to the kind and amount of electrical activity of the frontal lobe of the brain is upheld. This relationship is thought to be the result of metabolic dysfunction of the cortical neurons and of the perturbation of inhibitory and facilitatory circuits between the mid-brain and the frontal cortex.

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BIOGRAPHICAL ITEMS

Will Alan Justiss was born February 1, 1920, in Ravencroft, Tennessee. He enrolled in Jacksonville Junior College, Jacksonville, Florida in June 1948 and received the Associate of Arts degree in June 1950. He entered the University of Florida in 1950 and received the degree of Bachelor of Arts from the College of Arts and Sciences in 1952.

In 1952 he entered the Graduate School of the University of Florida and received the degree of Master of Arts in Psychology in 1954.

Mr. Justiss was awarded a pre-doctoral Research Fellowship by the National Institutes of Mental Health in 1955 and returned to the University of Florida to complete studies leading to the degree of Doctor of Philosophy in psychology.

He has held the positions of Research Assistant and Research Associate at the Moosehaven Research Laboratory. He is currently a Public Health Service Research Fellow of the National Institute of Mental Health (on leave) and holds an appointment of Director of Research (Acting) of the Moosehaven Research Laboratory, Orange Park, Florida.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 10, 1957

Stan E. Winkler
Dean, College of Arts and Sciences

Dean, Graduate School

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